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This TOP supersedes TOP 01-1-061, Corrosion and Deterioration Testing in Humid Tropic Environments, dated 4 November 1987.

Marginal notations are not used in this revision to identify changes, with respect to the previous issue, due to the extent of the changes.

14. ABSTRACT
This revised test operations procedure (TOP) describes general procedures for conducting corrosion and degradation tests of materials and materiel systems in humid tropic environments. The procedures presented in this TOP are a practical statement of exposure requirements to be used as a guideline for exposure testing in the humid tropic environment.

15. SUBJECT TERMS
Tropics, corrosion, deterioration, humidity, microbial activity, TRTC

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 01-1-061A — 21 July 2014
DTIC AD No.

CORROSION AND DETERIORATION TESTING IN THE HUMID TROPIC ENVIRONMENTS

*This TOP supersedes TOP 01-1-061, Corrosion and Deterioration Testing in Humid Tropic Environments, dated 4 November 1987.

Approved for public release; distribution is unlimited.

1. SCOPE.

a. This revised Test Operations Procedure (TOP) describes general procedures for conducting corrosion and degradation tests of materials and materiel systems in humid tropic environments.

b. The procedures presented in this TOP are a practical statement of exposure requirements to be used as a guideline for exposure testing in the humid tropic environment.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Laboratory facility	To measure physical properties of test material/materiel and to store control items under controlled environmental conditions.
Meteorological station	Instrumentation to collect data must be near test material/materiel.
Exposure racks	To securely anchor/expose test material/materiel at specific heights and angles.
Sample holders	To support test specimens in exposure racks.
Exposure sites	To expose material/materiel to selected natural humid tropic environments.

Exposure sites will be selected based on the expected environmental condition in which the test item will be used. Generally, selection of exposure sites should be made in the most severe yet most realistic natural environment available to increase the chances of detecting material/materiel degradation. Environmental parameters normally considered for site selection include the following:

a. Daily temperature (high, low, mean).

b. Humidity (high, low, mean).

c. Rainfall (monthly, daily).

d. Vegetation description (types, stem size, density, and height).

e. Solar radiation (intensity).

f. Soil (type).

g. Wind (direction and speed).

h. Salt content of air (chloride).

i. Microbial activity.

j. Insect activity (types and levels).

2.2 Instrumentation.

a. Field instruments. Accuracy of field instrumentation depends upon specific test requirements, which should be addressed during test planning. Remote, self-contained instrumentation is used to record climatological and test item data as follows:

(1) Air temperature.

(2) Surface temperature.

(3) Relative humidity (RH).

(4) Rainfall.

(5) Solar radiation.

(6) Wind speed.

(7) Wind direction.

(8) Salt content of air.

(9) Sample weight changes.

(10) Visual sample changes.

(11) Distances.

(12) Headings.

(13) Sample surface examinations.

(14) Sample measurements.

(15) Dimensions.

(16) Durability.

(17) Color changes.

(18) Microbial presence.

(19) Ozone, nitrous oxide, hydrocarbons, and sulfur compounds.

b. Laboratory instruments. Selected procedures for measurement of material characteristics will determine the required instruments for the exposure test. Required accuracy of these instruments usually will be given by selected standard procedures (e.g., National Institute of Standards and Technology (NIST) standards, American Society for Testing and Materials (ASTM) International standards) and should be addressed during test planning. Those instruments should be able to measure:

(1) Changes in tensile strength, elasticity, and elongation of materials.

(2) Surface deterioration, fungal growth and contamination.

(3) Material surface and subsurface flaws.

(4) Thickness, length, width, depth, inside/outside diameters, and other physical dimensions.

(5) Precise weight of test materials.

(6) Identify inorganic materials such as corrosion products.

(7) Identify chemical changes on surface of organic materials.

3. REQUIRED TEST CONDITIONS.

3.1 Test Planning.

Establish the scope and objective(s) of exposure tests. Tests may be planned to report any of the following:

a. Changes in the physical properties of materials or items after a specified exposure period.

b. Exposure time dictated by tactical doctrine for specific systems.

c. Exposure time to the occurrence of physical changes in material samples or events such as exposure to a specified amount of solar radiation.

d. Degradation profile, namely a record of a series of measurements of changes in physical characteristics after specified exposure periods.

e. Observations of a specific component or group of components in a materiel system known to have suffered environmental deterioration in a previous test.

f. Established fixed procedures for preparing, conditioning, and cleaning items. The procedures will vary with materials, but must be uniform to provide comparative results.

g. Established laboratory methods and procedures for measurement of item characteristics. When available, standard methods and procedures should be employed such as NIST or ASTM International standards.

h. Determination of required instrumentation and its accuracy for measurement of material/materiel characteristics in accordance with selected methods and procedures.

i. Designed data collection sheets for collection of field and laboratory test data.

j. Established corrosion/deterioration checklist (see Appendix A) to be used throughout all phases of testing, from receipt to final inspection. Use the checklist as a guide during visual inspection of the exposed material sample or item. The item or system should be examined to determine exactly what components or areas are to be inspected and what kinds of deterioration to expect. Specific areas for concern include the following:

(1) Areas which entrap water (corrosion or blistering of coatings).

(2) Areas which retain dirt or debris (corrosion, blistering of coatings, fungal attack).

(3) Areas where dissimilar metals are in contact (galvanic corrosion).

(4) Seams or crevices (crevice corrosion, coating defects, galvanic corrosion).

(5) High temperature areas (burned or damaged coatings, corrosion).

(6) Damaged coatings (blistering, chalking, corrosion).

(7) Mechanical damage (corrosion of unprotected surfaces, loss of camouflage).

(8) Areas exposed to chemicals such as battery boxes, human contact points, etc. (corrosion and blistering of coatings).

(9) Electrical components (water intrusion, galvanic corrosion, fungal growth).

k. For microbio1ogical inspections, the item or system should be examined to determine exactly what components or areas are to be inspected and what types of deterioration are expected.

l. Established length of the exposure; duration of exposure is determined by the requirement of the individual test and the item being tested. For example, materials such as ceramics deteriorate slowly over a period of years while unprotected carbon steel may be completely destroyed within eight weeks.

m. Established field inspection schedule and sample retrieval schedule. An appropriate schedule is critical to the test. The schedule is determined by the severity of the exposure site, the degradation characteristics of the material, test duration, and test objectives; this also may affect the established exposure time. The schedules in Table 1 are based on exposures at U.S. Army Tropic Regions Test Center (TRTC) sites and are intended for general guidance only.

TABLE 1. TYPES OF MATERIAL AND SUGGESTED INSPECTION SCHEDULES

MATERIAL	MINIMUM EXPOSURE TIME	INSPECTION SCHEDULES
Carbon steel (unprotected)	8 weeks	Weekly
Cotton fabric	1 year	Biweekly first 8 weeks, monthly thereafter
Plastics (polyvinyl chloride and nylon	1 year	Biweekly first 8 weeks, monthly thereafter
Vehicle/Artillery	1 year	Monthly
Ammunition/Missiles	1 year	Monthly
Fabric structures	6 months	Biweekly first 8 weeks, monthly thereafter
Electronic equipment	6 months	Biweekly first 8 weeks, monthly thereafter
General clothing and equipment	6 months	Biweekly first 8 weeks, monthly thereafter

n. Estimated total sample size required to meet the test objectives. Estimation should be based on the test requirements, exposure duration, retrieval/inspection schedule, type of laboratory test (destructive/nondestructive), repeatability of measurement techniques, expected material deterioration patterns, and prior knowledge of material homogeneity. Sample size must include a sufficient number of samples to serve as control samples.

o. Established experimental designs and statistical analyses proposed for addressing the objectives of the exposure test.

p. Prepared test operations and inspection checklists using the checklist provided in Appendix A, and systems manuals as guides. The test operations checklist should cover specifics for the test item/material and test milestones.

3.2 Test Site Selection.

The TRTC operates a number of sites available for exposing items in Panama. These sites provide various tropic macro-environments, each one having peculiar conditions which accelerate specific environmental effects. During the test planning phase, the appropriate exposure site should be selected based on the unique requirements of the test item. A brief description of the general environmental conditions at each site is presented in Appendix D. A number of different micro-environments may also be found at each exposure site. These micro-environments should be considered when selecting a specific location within the selected site because each micro-environment affects the material/item differently.

3.3 Exposure Mode Selection.

Depending on intended use or storage, material/ materiel being tested may be exposed in any of the following modes which characterize various degrees of exposure to ambient conditions:

a. Direct Exposure: exposure to all prevailing atmospheric elements.

b. Open Shed: exposure under a roofed structure with open sides permitting free air flow but not subject to direct sunlight and rainfall.

c. Covered: normally, exposure on a pallet with the test items covered with a tarpaulin to exclude direct sunlight and rainfall. This is an accelerated method which gives high induced temperatures and reduced evaporation of moisture.

d. Warehouse: exposure in a building, tent, or bunker.

4. TEST PROCEDURES.

4.1 Procedure for Materiel System Tests.

4.1.1 Facilities.

Sites for testing materiel systems for corrosion/deterioration resistance include the full range of humid tropic environments described in Army Regulation (AR) 70-38[**1] as Constant and Variable High Humidity Daily Cycles of the Basic Climatic Design Type. They include forested sites of classic jungle vegetation where temperatures are virtually constant day or night throughout the year at about 24 °Celsius (C) (75 °Fahrenheit (F))with relative humidity constantly at 94 -100 percent with occasional drops to 80 percent. Open test areas (inland, coastal, and breakwater) vary in temperature throughout the day from about 21 to 36 °C

**Superscript numbers correspond to Appendix F, References.

(70 to 97 °F), with relative humidity levels that range from saturation at night to about 75 percent during the hottest part of the day. Coastal and breakwater sites have high levels of atmospheric salt fall that combine with the high temperature and relative humidity levels to produce an environment that is extremely corrosive to metals. Intense solar radiation in open areas and high levels of biological activity in forests produce rapid degradation of susceptible nonmetallic materials. Sites should be selected with the military use of the item in mind.

4.1.2 Receipt Inspection.

This serves a twofold purpose: to document the condition of the item or system as received for testing, and to assist in formulating inspection procedures after the item has been stored or performance tested. Careful attention must be given to area of preexisting corrosion, as well as areas which may ultimately suffer attacks (see paragraph 3.1.j). The appropriate operation/maintenance manuals for the item or system must be reviewed for prescribed inspections, but receipt inspection will not necessarily be limited to those areas.

4.1.3 Performance/Exposure Inspection.

Deterioration will progress at varying rates during performance testing and also during storage or exposure. Sufficient time must be allowed for potential degradation to become observable and to give evidence of its effects on performance, structural integrity, and durability in general. Regularly scheduled inspections will identify degradation soon after it occurs and allow reasonable estimates of its impact on the item. The test plan should address specific details for scheduled inspections. Guidance is given in Table 1. Initial appearance and significant advances or changes in degradation should be documented in test incident reports (TIRs) as well as in the Test Officer's logbook for inclusion in other reports.

4.1.4 Final Inspection.

This is the climax of the test as far as corrosion and other deterioration are concerned. This inspection must be done diligently and with extreme attention to detail, since it is the last chance to document potential problems with the test item. Again, all areas that have the potential for corrosive or deteriorative attack (see paragraph 3.1.j) must be inspected and each type of attack and its location carefully documented.

4.1.5 Suggested Improvements.

When corrosion or any degradation is observed, an attempt should be made to analyze the failure or deterioration to avoid the problem in the future. When possible, it is incumbent upon test personnel to suggest improvements in item design, materials, or protection schemes to enhance the life or serviceability of the item. Suggestions will be placed in TIRs or final reports.

4.1.6 Data Required.

a. Ambient temperature (minimum, maximum, average (mma)).

b. Relative humidity (mma).

c. Wind speed (mma).

d. Wind direction (hourly).

e. Solar radiation (total, horizontal/vertical, wavelength intensity).

f. Rainfall (total and intensity).

g. Salt fall (total), as required.

h. Other air contaminants, as required.

i. Corrosion/deterioration observed by using corrosion/deterioration checklist developed from paragraph 3.1.j.

4.2 Procedures for Material Sample Exposure Tests.

4.2.1 Facilities.

a. Exposure site.

(1) Measure and record appropriate environmental conditions.

(2) Install exposure rack(s). The area beneath the racks should be typical of the ground cover at the site.

b. Install selected instrumentation for measurement of climatological data.

c. Exposure rack design depends on the size and characterization of the test material. Racks and associated hardware should be constructed of materials that are highly resistant to corrosion. Aluminum alloy No. 6061-T6 and Monel are recommended as construction materials. Generally the racks should be designed to position the exposed surfaces of the material samples at an angle of 30 degrees to the horizontal facing east. For some materials, other orientations such as vertical or horizontal may be required. The exposure rack should not constitute a backing for the samples. The rack should be designed so that the lowest samples positioned on the rack are exposed at a minimum height of 76 centimeters (cm) (30 inches) above ground level, unless otherwise required by the expected use of the test material.

d. Sample holders should be constructed of an inert material, such as ceramic insulators, aluminum extruded shapes, or Plexiglas strips. The sample holders should be designed so that the specimens cannot shift position, yet not be constrained (i.e., be free to expand or contract with thermal changes, swell from moisture absorption, or shrink because of plasticizer loss). The geometric shape, expected static or dynamic stress use/conditions, physical size, weight, flexibility, and resistance to air flow of the samples must be considered in the selection of the sample holders. Unless specified by the design, the sample holder should not constitute a backing for the portion of the material to be evaluated.

4.2.2 Instrumentation.

Ensure that all field and laboratory instruments are working properly and calibrated in accordance with AR 750-25[2].

4.2.3 Test Samples.

a. Test samples should be procured from the same material lot to optimize homogeneity. The samples should be prepared and conditioned identically in accordance with selected procedures (paragraph 3.1.f).

b. Exposure test samples may be of any size or shape that can be mounted in a holder directly applied to the racks or as specified by the appropriate test design. The specimens must be of sufficient dimension from which suitable samples may be cut for evaluation. Exposure test samples should be large enough so in case the mounting edges need to be removed, it does not affect the results of the evaluation.

c. Normally, all materials of unknown end-use application will be exposed in an unbacked condition. Backing shall be used only to simulate an end-use system rather than as a standard mounting method. The effect of backing is highly significant and may contribute to the degradation as a function of reflectance and heat absorption. When conditions of use are known, the sample exposed will be emplaced in a manner that conforms to proposed use.

d. All test samples should be marked with appropriate identification which must remain legible throughout the exposure period. The rack itself and the position on the rack should be identified. After all samples are placed on the racks, the Test Officer should have a detailed sketch and photographic record of the completed rack with all the appropriate markings and identifications.

e. The specimens to be removed after each retrieval interval should be determined before their exposure. These specimens should be exposed randomly on different racks to ensure a representative exposure.

f. Packaging is an important factor to be considered before exposing the material. The packaging method should not damage or alter any properties of the specimens while transporting the retrieved specimens back to the laboratories for detailed analysis. Preferably, each specimen should be wrapped individually in an inert envelope such as paper or plastic. When specimen surfaces are to be examined, soft, padded tissue should be used to wrap the specimens before placing them in plastic bags which should be sealed as appropriate. Since the material is sensitive to humidity, desiccant packs must be used. Ship specimens by the fastest method available.

4.2.4 Control Samples.

There are two types of control samples: aged and unaged.

a. Unaged control samples are those material samples tested prior to any storage or exposure. The resulting test data are used as baseline data (zero time on the performance-versus-exposure time graphs) and for confirmation of the previous assumption of the degree of sample homogeneity used for estimating the total sample size required for the exposure test. The size of the sample allocated to this control group should be determined by a statistician experienced in experimental design. Based on the test results of the unaged control samples, modification of the sample-retrieval schedule or changes to the exposed sample size(s) may be required for achievement of the test objectives.

b. Aged control samples are those material samples stored at controlled standard conditions of 23 ±3 °C (73 ±5 °F) and 50% ±2% humidity and covered with inert wrapping to exclude light exposure unless otherwise specified by test requirements. These samples are removed periodically from controlled storage and are tested in the laboratory along with exposed samples. Test data are used to identify the occurrence of non-tropic deterioration effects and systemic errors in laboratory test procedures. Sufficient material samples should be allocated to this control group to obtain statistically significant test results. A statistician should estimate the required sample size. Aged control samples are also used for comparison purposes during field inspection of the exposed samples.

4.2.5 Test Controls.

a. Ensure that all sensors, recorders, and instrumentation are working properly and calibrated.

b. Ensure that clean plastic gloves are worn at all times when emplacing and removing material samples to avoid sample contamination.

c. Perform periodic inspections of the exposure site(s) to ensure materials are properly exposed in accordance with test design.

d. Procure test samples from the same material lot to optimize sample homogeneity.

e. Provide for unaged and aged controls samples (paragraph 4.2.4).

f. Utilize random techniques for the following actions. (Consult a statistician for proper randomization procedures.)

(1) Sample selection from material lot.

(2) Sample allocation (control and exposed samples).

(3) Sample emplacement on exposure rack(s).

(4) Sample retrieval from exposure rack(s).

(5) Laboratory testing of samples (control and exposed samples).

4.2.6 Test Method.

a. Install material samples on exposure racks in accordance with planned specimen layout (paragraph 4.2.3).

b. Inspect the exposed material samples in accordance with the field inspection schedule (paragraph 3.1.j and Table 1).

c. Record data on Inspection Data Sheet(s) as shown in Appendix B. During field inspection, exercise caution when inspecting the material samples; samples should not be disturbed unless specified by the test plan.

d. Retrieve material samples in accordance with the retrieval schedule (paragraph 3.1.j and Table 1).

e. Package samples in accordance with established packing instructions (paragraph 4.2.3.f).

f. Transport samples to the laboratory expeditiously.

g. Perform laboratory tests on the retrieved samples to determine changes in physical properties. Perform laboratory tests concurrently on samples from the aged control group.

h. Record data on inspection or test data sheets.

i. Compile and analyze test data.

j. When appropriate, adjust field-inspection and sample-retrieval schedules as data are compiled and analyzed to obtain meaningful test results or to reduce test costs.

NOTE: Some exposure sites may be more or less severe to the specific items under test than originally estimated; therefore, adjustments in schedules may be expected.

4.2.7 Data Required.

a. Test method documentation.

(1) Describe exposure site(s) and mode(s) to include the following:

(a) Soil (type).

(b) Vegetation (type, stem size and spacing, and canopy height).

(c) Ground cover (type in immediate vicinity of exposure racks).

(d) Slope of site (percent).

(2) Physical location of meteorological facility relative to test site(s).

(3) Description of exposure rack(s) and sample-holder construction.

(4) Orientation of exposure rack(s) to include the following:

(a) Rack elevation.

(b) Exposure angle.

(c) Rack azimuth.

(5) Method of mounting samples.

(6) Record of material sample layout on exposure racks.

(7) Description of material samples including photographs and identifying marks.

(8) Description of sample conditioning and cleaning procedures.

(9) Identification of laboratory test(s) to evaluate material deterioration.

(10) Identification of scoring standards for visual inspections.

(11) Results of laboratory tests of control specimens (baseline data).

(12) Exposure test duration.

(13) Field inspection and sample retrieval schedules.

b. Test results documentation.

(1) Daily meteorological data to include the following:

(a) Ambient temperature (mma).

(b) Relative humidity (mma).

(c) Wind speed (mma).

(d) Wind direction (hourly).

(e) Solar radiation (total, horizontal/vertical, wavelength/intensity).

(f) Rainfall (total and intensity).

(g) Salt fall (total), as required.

(h) Other air contaminants, as required.

(i) Corrosion/deterioration observed by using corrosion/deterioration checklist developed from paragraph 3.1.j.

(2) Field inspection data for each material sample in accordance with Appendix B Inspection Data Sheet.

(3) Laboratory test data for each sample (measurements of physical properties of materials).

(4) Location, duration, and dates of exposure for each sample.

(5) Presence, extent, and identification of biological growth on the exposed samples, with estimate of effect on properties and serviceability of material.

(6) Material surface deterioration (visual and microscopic effects, chalking, roughness, crazing, corrosion, etc.).

5. DATA REQUIRED.

The data required for this procedure are addressed in paragraphs 4.1.6 and 4.2.7.

6. PRESENTATION OF DATA.

a. Present the data outlined in paragraphs 4.1.6 and 4.2.7 in narrative, tabular, or chart format, as appropriate.

(1) A sample of data in tabular form is provided as Table 2.

TABLE 2. SUMMARY OF METEOROLOGICAL DATA

	Inside Temp (°C)[a]			Inside RH (%)[a]			Outside Temp (°C)[a]			Outside RH (%)[a]		
Date	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**
30-Apr-08	35.35	25.28	29.32	81.9	30.6	62.9	36.70	21.36	28.07	93.6	26.4	70.5
1-May-08	33.27	25.14	28.26	86.2	39.6	73.1	35.76	22.11	27.11	95.0	32.5	79.6

[a]NOTE: Samples were exposed inside a warehouse at Corozal, Panama. The meteorological station collected data from two sensors: one located by the samples and another one located outside, by the roof of the warehouse.

(2) A sample of data presented in narrative form is provided below:

"The acetate samples in the compost pile showed an immediate and significant weight loss. Maximum loss occurred in 10 days as opposed to 30 days for air exposure and 50 days in litter exposure. Investigation showed that plasticizer loss was mainly responsible for the decrease in weight. Nylon samples lost about 4 percent of their original weights after 4 weeks of exposure and thereafter remained chemically stable."

b. Compute the sample mean and standard deviations of the measured properties of the materials/items, and tabulate by exposure site, mode, and length of time.

c. Perform statistical tests to determine significance of changes in properties of exposed material, as required.

d. Present graphs and photos for significantly different groups of data to show changes in properties versus exposure times or other parameters.

(1) A sample of data provided in graphic format is shown in Figure 1.

(2) A sample of photographic documentation is shown in Figure 2.

e. Analyze the data as required to determine whether observed changes in material properties are statistically related to specific environmental conditions.

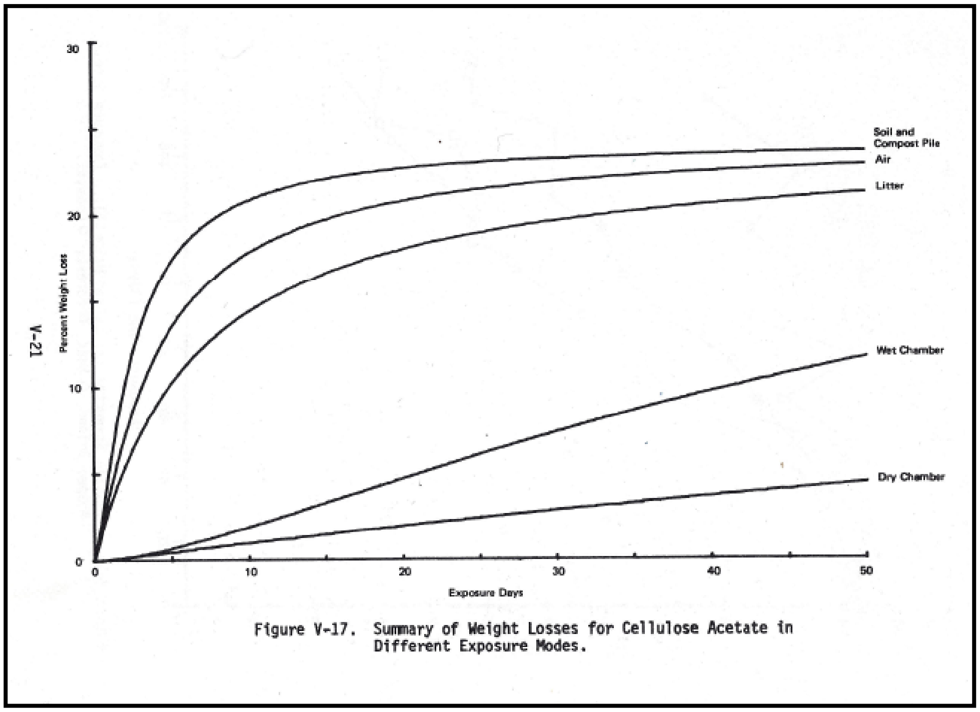
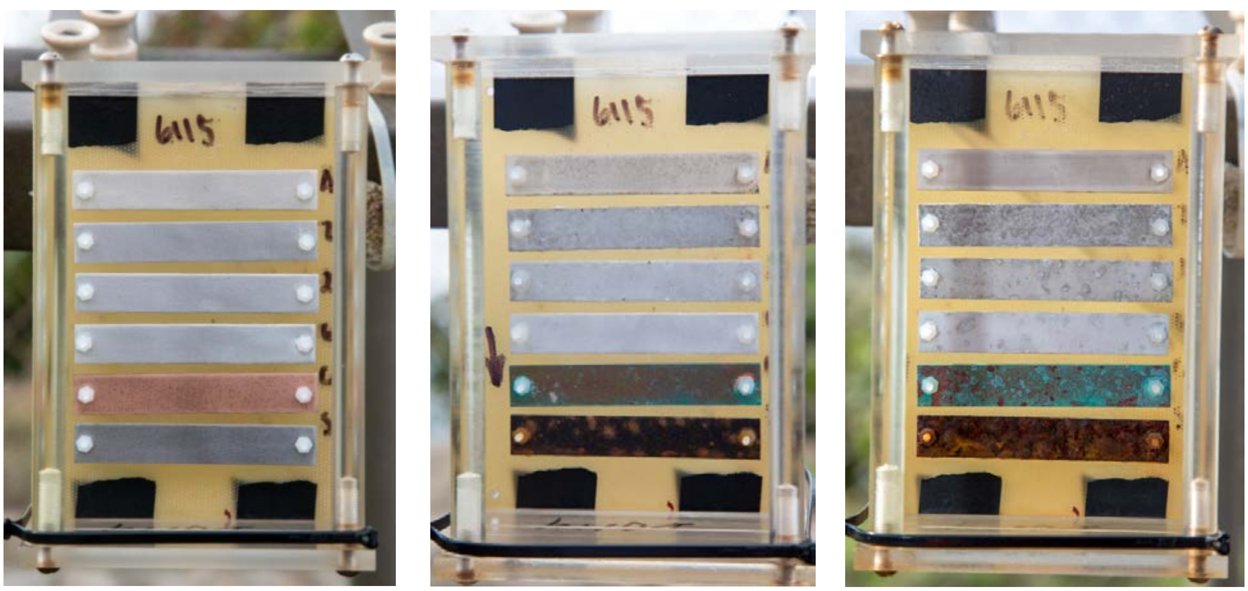


Figure 1. Sample data presented in graphical format.

Visual comparison of deterioration of metal coupons on exposure racks at Marine Breakwater Exposure Site, Sherman, Republic of Panama.



12 March 2013 (Start of test)	2 April 2013 (After 3 weeks of exposure)	13 May 2013 (After 9 weeks of exposure)

Figure 2. Sample of photographic documentation.

APPENDIX A. SAMPLE TEST OPERATIONS CHECKLIST.

	Item	Yes	No	NA
1.	Scope and objectives of exposure test established?	☐	☐	☐
2.	Exposure site(s) and mode(s) selected?	☐	☐	☐
3.	Methods and procedures selected for measurement of properties of items?	☐	☐	☐
4.	Scoring standards selected for visual inspections?	☐	☐	☐
5.	Field and laboratory instruments with required accuracy procured?	☐	☐	☐
6.	Length of exposure test and sample size determined?	☐	☐	☐
7.	Field inspection schedule established?	☐	☐	☐
8.	Sample retrieval schedule established?	☐	☐	☐
9.	Baseline data (control samples, paragraph 4.2.4) collected and analyzed?	☐	☐	☐
10.	Exposure rack(s) and sample holder(s) constructed?	☐	☐	☐
11.	Meteorological site(s) established?	☐	☐	☐
12.	Required preparatory data (paragraph 4.2.7.a) recorded?	☐	☐	☐
13.	Items or samples emplaced at exposure site(s)?	☐	☐	☐
14.	Test milestones completed? (List test milestones by date; check off as accomplished)	☐	☐	☐
15.	All modifications to initial test design documented?	☐	☐	☐
16.	Required test data (paragraph 4.2.7.b) recorded?	☐	☐	☐

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APPENDIX B. SAMPLE TEST INSPECTION DATA SHEET.

PROJECT No.: ____

SITE: ____

DATE: ____

WEATHER CONDITION: ____

INSPECTOR: ____

SAMPLE No.: ____________________ RACK No.: ____________________

DESCRIPTION OF SAMPLE OR AREA EXAMINED (component, item, location on item, etc.):

____

1. General Appearance: ____

   a. Surface nature (Describe): ____________________________________

   b. Surface damage (if yes, type of damage) Yes ____ No ____

Broken?	Yes ____	No ____
Cracks?	Yes ____	No ____
Scoring?	Yes ____	No ____
Crazing?	Yes ____	No ____
% of damage ______________		

   c. Color.

   Compare exposed sample with aged control samples and describe differences:

   ____

   If new color, identify using Munsell Color Guide: ______________________

   Fading? Yes ____ No ____

   d. Is sample………………Transparent? Yes ____ No ____

   Translucent? Yes ____ No ____

   Opaque? Yes ____ No ____

   e. Appearance……………Glossy _____ Dull _____

APPENDIX B. SAMPLE TEST INSPECTION DATA SHEET.

2. Debris (any foreign matter on sample):

a. Percent top surface coverage: ____

b. Percent bottom surface coverage: ____

c. Color of: ____

d. Shape of: ____

e. Imbedded in material? Yes ____ No ____

If No, is it loose? Yes ____ No ____

If Yes, give depth: __________% Coverage: ____________

f. Identify nature of debris. (use of microscope is recommended.):

Salts? Yes ____ No ____

Corrosion products? Yes ____ No ____

Soil? Yes ____ No ____

Plant exudations? Yes ____ No ____

Seeds? Yes ____ No ____

Pollen? Yes ____ No ____

Spores? Yes ____ No ____

Algae? Yes ____ No ____

Insect eggs? Yes ____ No ____

Other? Yes ____ No ____ If Yes, identify:

____

g. Collect debris for laboratory analyses.

3. Surface temperature (if required) ________________

4. Corrosion.

a. Color(s) (Describe): ____

b. Texture (Describe): ____

c. Percent top surface coverage(s): ____

d. Percent bottom surface coverage(s): ______________________________________

e. Location(s) (Describe; use photographs or line drawings for clarity): __________

____

____

APPENDIX B. SAMPLE TEST INSPECTION DATA SHEET.

5. Condition (material sample exposure)

a. Is sample on the rack? Yes ____ No ____

If No, is it on the ground? Yes ____ No ____

(Identify) ________________________________

If No, is it missing? Yes ____ No ____

b. Is the sample damaged? Yes ____ No ____

If Yes, by what and to what extent? (Describe) __________________________

____

c. Is the rack damaged? Yes ____ No ____

If Yes, by what and to what extent? (Describe) __________________________

____

6. Other comments (e.g., changes in dimensions because of stretching, swelling, or shrinking):

____

____

____

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APPENDIX C. IMPORTANCE OF ENVIRONMENTAL PARAMETERS.

C.1. TEMPERAURE.

The rate of chemical reactions increases as the temperature increases. Many microorganisms exhibit maximum growth when temperatures are between 24 and 36 °C (75 and 97 °F). Consideration should be taken to measure air and surface temperatures if the study is designed to develop cause-effect relationships.

C.2. HUMIDITY.

Condensation becomes a problem when the relative humidity approaches 100 percent. Water, as vapor, can diffuse into almost any container through pinholes or cracks and condense there. Water helps deteriorate materials by serving as the following:

a. A trap for nutrients for bacteria, fungi and other microorganisms.

b. A transport medium for chemicals.

c. A medium for chemical reaction.

d. A hydration agent for dry materials causing them to swell.

C.3. RAINFALL.

Tropical rainfall is usually a heavy downpour of relatively short duration. Two important effects on materials are as follows: thermal shock due to rapid cooling caused by water on hot surfaces and wetting of surfaces, thus initiating corrosion processes. Rain water normally contains dissolved salts and is saturated with oxygen. This water provides an electrolytic path for corrosion propagation.

C.4. VEGETATION.

Some types of vegetation tend to exude tannins, sugars, and other natural plant products which may support microbial growth and corrosion processes.

C.5. SOLAR RADIATION (to include ultraviolet radiation).

Radiation can damage exposed samples causing cross linking and changes in polymeric structure and color. Solar radiation may damage heat sensitive items and cause softening of polymers and evaporation of solvents and plasticizers.

C.6. SOIL TYPE.

Soil chemistry and surface water influence corrosion processes of materials used or stored near ground level.

APPENDIX C. IMPORTANCE OF ENVIRONMENTAL PARAMETERS.

C.7. WIND DIRECTION AND SPEED.

Wind direction and intensity will influence the amount of particulates that impinge on test material. At coastal sites moisture and salt are also transported by wind.

C.8. SALT CONTENT IN AIR.

Salt content in air will affect the rate of electrolytic corrosion of metals. Sites with high atmospheric salt levels exhibit high corrosion rates.

C.9. MICROBIAL ACTIVITY.

Microbial activity is important whenever microorganisms use the exposed sample as a nutrition source and allied metabolic products are detrimental to the material.

C.10. INSECT FAUNA.

Exposed items, in many instances, serve as food and as a habitat for a variety of insects. Metabolic waste from these insects may damage the exposed items through the action of organic acids or by acting as a substrate for microbial attack.

APPENDIX D. DESCRIPTION OF EXPOSURE SITES.

D.1. TRTC operates exposure sites in Suriname and the Panama Isthmus. A description is given of the severity of several exposure sites for selected materials in the U.S. Army Tropic Test Center (USATTC) report, Determination of Optimum Tropic Storage and Exposure Sites[3]. The climate of the USATTC sites is classified as either constant high humidity (B1) or variable high humidity (B2) by AR 70-38. Additional exposure testing data may be found in the USATTC report, Materiel Testing in the Tropics[4].

D.2. Atlantic side of the Panama Isthmus. There are three exposure sites (Table D-1) which are open (no shade), and available for direct and open shed exposure modes. Exposure racks are available on site, inside secured area at three locations depicted in Figure D-1. The annual average temperature in this area is 27 °C (81 °F) and temperature ranges from 22 °C to 33 °C (71 °F to 92 °F). The annual average RH is 85% and RH ranges from 51% to 98%. The annual average rain in Sherman is 105 inches per year with an average of 216 days of rain/drizzle per year.

TABLE D-1. EXPOSURE SITES ON THE ATLANTIC SIDE OF PANAMA

EXPOSURE SITE	LATITUDE	LONGITUDE
Marine Breakwater	9°22'24.84"N	79°56'50.42"W
Coastal	9°22'19.14"N	79°57'01.72"W
Inland	9°21'42.09"N	79°57'15.78"W

Figure D-1. Exposure sites on the Atlantic side of the Panama Isthmus.

APPENDIX D. DESCRIPTION OF EXPOSURE SITES.

a. The Marine Breakwater Exposure Site is located on the west breakwater at the northern entrance of the Panama Canal. The area is barren with sparse vegetation. The wind blows continuously from the north. There is considerable salt spray due to the combined effect of continuous wave action and wind.

b. The Coastal Exposure Site is located 500 meters west of the breakwater site. Although it is located on the coast, it is not directly on the beach. The atmospheric salt content is much less than at the breakwater site (although greater than at inland sites), vegetation is sparse with no trees for shade.

c. The Inland Exposure Site is about 1.6 kilometers southwest of the breakwater site. The atmospheric salt content is much less than that of the coastal or breakwater sites. The site floor is covered by grass, and there is no vegetation to shade the exposure racks.

D.3. Pacific side of the Isthmus. TRTC has control over three exposure sites (Table D-2). Two of them (Cerro Tigre and Horoko) are considered forest exposure sites located in a tropical moist forest, based on the Holdridge life zones system[5]. They have negligible salt fall and solar radiation but provide extreme humidity, rainfall, fungus, organic particles, and insect exposure. These sites present various types of jungle terrain including multiple canopied forests, open areas with grassland, and unobstructed open areas. The trees are considered mature. All three sites are secured areas and provide guards on duty 24 hours a day.

TABLE D-2. EXPOSURE SITES ON THE PACIFIC SIDE OF PANAMA

EXPOSURE SITE	LATITUDE	LONGITUDE
Cerro Tigre	9° 3'55.01"N	79°37'43.70"W
Horoko	8°57'51.98"N	79°36'24.23"W
Corozal	8°59'6.73"N	79°34'8.59"W

a. The test area in Cerro Tigre has a variety of exposure sites, including forest, under canopy, open, creek, slope, grass lands, and other exposure sites. Shelters and cages are available. The annual average temperature is 26 °C (79 °F) with temperature ranging from 18 °C to 37 °C (64 °F to 99 °F). The annual average RH is 84% and it ranges from 25% to 98%. The annual average rain is 73 inches per year with an average of 269 days of rain/drizzle per year. Figure D-2 depicts the aerial view of the Cerro Tigre area.

APPENDIX D. DESCRIPTION OF EXPOSURE SITES.

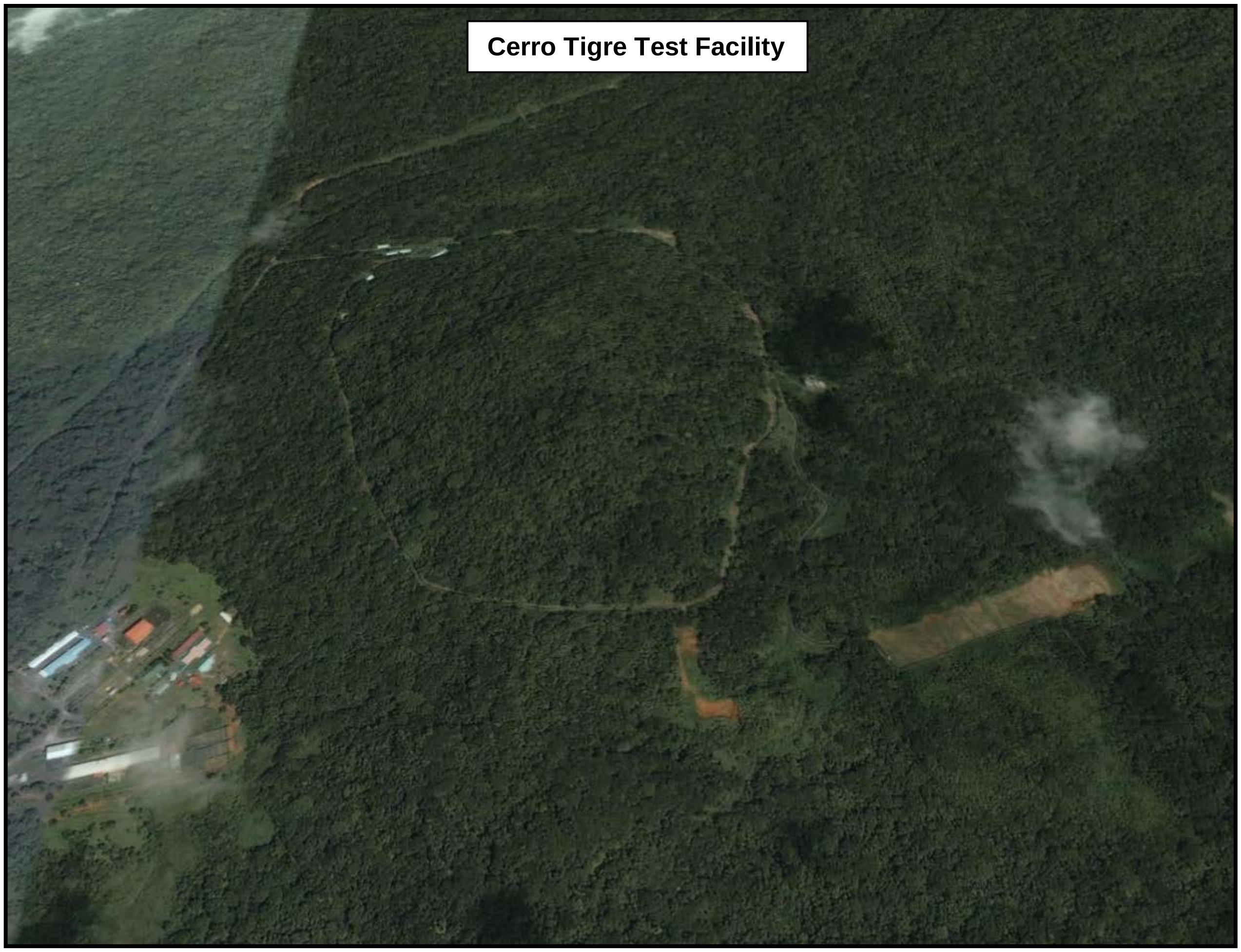

Figure D-2. Aerial view of Cerro Tigre Facility.

b. The test area in Horoko has multiple exposure locations including forest exposure sites, under canopy and open areas. The annual average temperature in this area is 27 °C (81 °F) and temperature ranges from 25 °C to 31 °C (77 °F to 88 °F). The annual average RH is 85% and it ranges from 47% to 100%. The annual average rain is 77 inches per year with an average of 142 days of rain/drizzle per year. Figure D-3 depicts the aerial view of Horoko area.

APPENDIX D. DESCRIPTION OF EXPOSURE SITES.

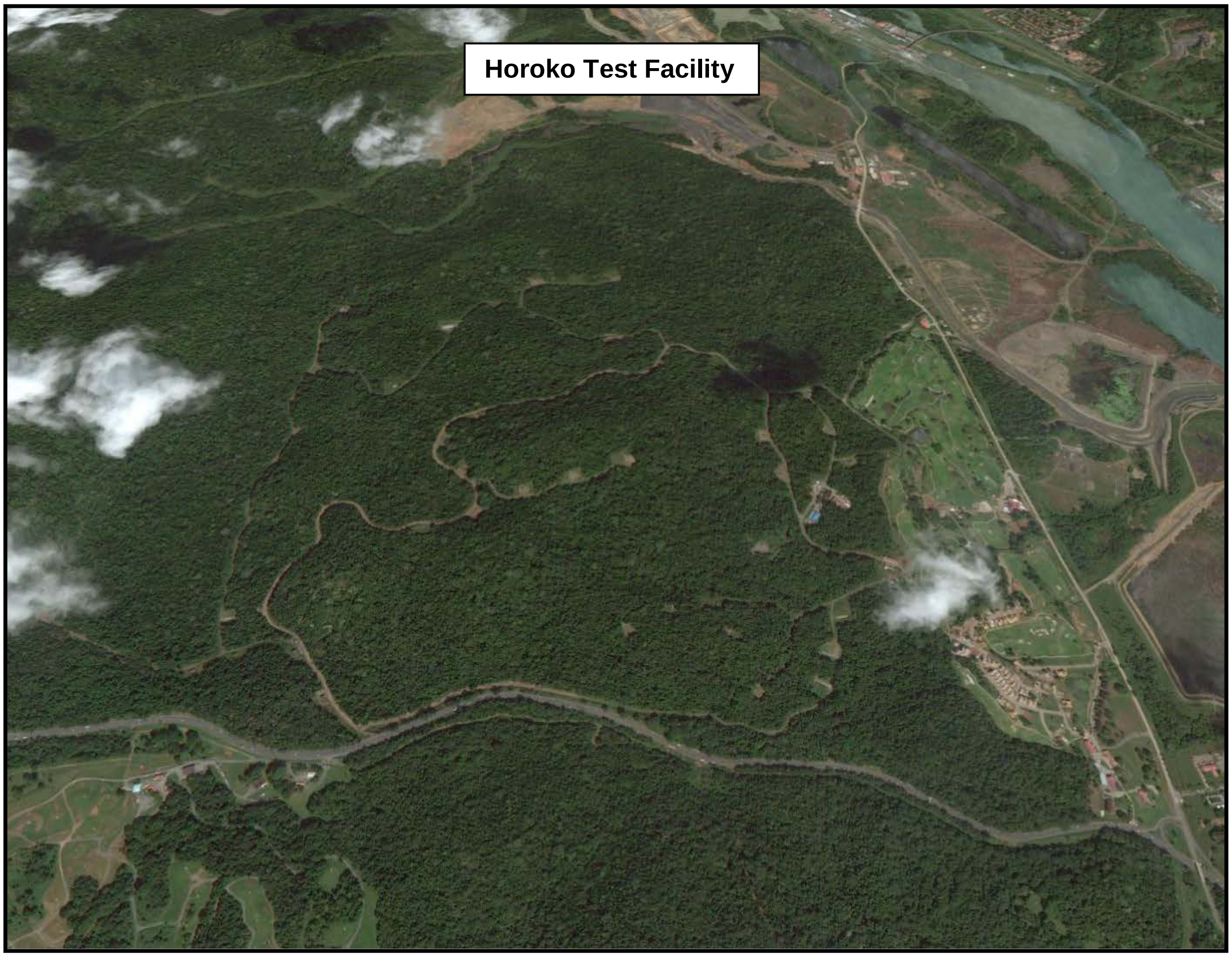

Figure D-3. Aerial view of Horoko Facility.

c. Corozal offers buildings that have covered uncontrolled (building 10) and controlled (building 19) climate areas. The annual average temperature in this area is 27 °C (81 °F) and temperature ranges from 20 °C to 37 °C (68 °F to 98 °F). The annual average RH is 80% and it ranges from 26% to 96%. The annual average rain is 71 inches per year with an average of 152 days of rain/drizzle per year. Figure D-4 presents location of buildings 10 and 19 inside Corozal complex.

APPENDIX D. DESCRIPTION OF EXPOSURE SITES.

Figure D-4. Exposure locations at Corozal.

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APPENDIX E. ABBREVIATIONS.

AR	Army Regulation
ASTM	American Society for Testing and Materials
C	Celsius
cm	centimeter
F	Fahrenheit
mma	minimum, maximum, average
NIST	National Institute of Standards and Technology
RH	relative humidity
TIR	Test Incident Report
TOP	Test Operations Procedure
TRTC	U.S. Army Tropic Regions Test Center
USATTC	U.S. Army Tropic Test Center

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APPENDIX F. REFERENCES.

1. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 15 September 1979.

2. AR 750-25, Army Test, Measurement, and Diagnostic Equipment, Calibration and Repair Support Program, 1 September 1983.

3. Sprouse, J.F.; Neptune, M.D.; and Bryan, J.C., Determination of Optimum Tropic Storage and Exposure Sites, Report II, Empirical Data. Canal Zone, U.S. Army Tropic Test Center, TECOM Project No. 9-CO-009-000-006, AD No. A005017, USATTC Report No. 7403001, March 1974.

4. Materiel Testing in the Tropics, U.S. Army Tropic Test Center, TECOM Project No, 9-CO-150-000-099, USATTC Report No. 790401, April 1979.

5. Holdridge, L.R., et al, Forest Environments in Tropical Life Zone: A Pilot Study. London: Pergamon Press, 1971.

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APPENDIX G. APPROVAL AUTHORITY.

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 01-1-061A, Corrosion and Deterioration Testing in the Humid Tropic Environments, Approved for Publication

1. TOP 01-1-061A, Corrosion and Deterioration Testing in the Humid Tropic Environments, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This revised TOP describes general procedures for conducting corrosion and degradation tests of materials and materiel systems in humid tropic environments. The procedures presented in this TOP are a practical statement of exposure requirements to be used as a guideline for exposure testing in the humid tropic environment.

2. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 2202 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Date: 2014.07.31 12:29:14 -04'00'

MICHAEL J. ZWIEBEL
Director, Test Management Directorate (G9)

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Range Infrastructure Division (CSTE-TM), US Army Test and Evaluation Command, 2202 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: US Army Yuma Proving Grounds, Tropic Regions Test Center (TEDT-YPT), 301 C. Street, Yuma, Arizona, 85365. Additional copies can be requested through the following website: http://www.atec.army.mil/publications/topsindex.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.